A SUGGESTION REGARDING HEAVY AND LIGHT SEED GRAIN[1]

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A considerable amount of work has been done by investigators of cereals, regarding the comparative value of heavy and light grains used as seed. The major portion of the experiments have been conducted with wheat, oats and barley. The problem appeared simple at the beginning, but has developed many complications.

In many cases bulk grain has been graded into various classes without determining the relative number of grains per measured quantity. Thus the experiments have been vitiated by the failure to consider the different rates of seeding, as regards the number of grains per area, which would naturally ensue. Even if allowance for seeding were made, and the number of grains per area determined as accurately as possible, it would be an excellent thing to conduct also a rate of sowing test. Such a test might throw light upon results induced by climatic conditions.

Some of the workers have made no distinction between shriveled grains and small plump grains. To eliminate the factor of shriveled grains would be virtually doing away with fanning mill methods of grading, which would seem to be necessary if we are to simplify the problem and to obviate the conflicting factors. Zavitz, of Ontario, has worked with small, hand-picked samples of grain and has evidently succeeded in overcoming the difficulties mentioned. His results, extending over a series of years, are remarkably consistent and worthy of careful study.

Despite some of the errors one can not fail to be impressed, as the literature is studied with the preponder-

[1] Contribution No. III, Laboratory Experimental Plant-breeding, Cornell University.

ance of evidence in favor of the large seed. The errors are as apt to tell against the heavy seed as against the light seed. In fact, where error has been most carefully eliminated, as in the experiment of Zavitz, the large seed gives the most striking positive results.

The result, empirically derived, while of great practical importance, does not throw much light on transmission. The majority of the experimenters have paid no attention to the *plants* from which the large or small grains have come. Bolley selected large and small grains from the same heads of wheat and found that the large grains generally produced the largest yields. Lyon has stated that both large and small grains in a lot of wheat must represent both large and small spikes, and if only large grains are sown one is not necessarily selecting from the best plants.

If, according to Johannsen,[2] "In a population containing only one single type, the selection of fluctuations has no action at all," then it would make no difference, as far as transmission is concerned, if all sorts of plants were represented in the seed, so long as we are dealing with a pure line. Most American breeders, however, would prefer to select for seed the best plants from the field each year, even if working with a pure strain. This practice is doubtless based on opinion at the present time rather than on well-grounded experimental knowledge. We ought to be willing to acknowledge our ignorance of the possibility of changing the type by selecting fluctuations of close pollinated cereals. Until more and accurate data can be secured a neutral position is much the better.

Correlation Data of Oats

The writer, in securing some statistical data on oats preparatory to breeding, noticed that the data were interesting in connection with the question of light and heavy seed. Measurements were taken on 1,000 oat culms grown at Dickinson, North Dakota, under field conditions. In nearly all cases, each head-bearing culm measured rep-

[2] Rpt. Third Int. Conf. on Genetics, London, 1906.

X_1 \ X_2	−22	−20	−18	−16	−14	−12	−10	−8	−6	−4	−2	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	No. of grns.
	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	
—10 150 159	1	1																															2
— 9 160 169						1				1										1													3
— 8 170 179							1				1			1				1								1						1	7
— 7 180 189										1				1	1	2	3	3	1		1	2								1			18
— 6 190 199									1		1	1	1	3	2	4	3	2	1	2	2	1	1			1		2					28
— 5 200 209	1			2		1		2	1	3	9	4	3	6	3	3	4	6	5	3	5	2		3	1	1	1	2		1	1		73
— 4 210 219		2		3	1	1	2	3	5	3	5	5	3	13	8	4	6	4	5	5	3	2	3	3		1			1				91
— 3 220 229				1	1	4	3	5	5	6	11	6	5	6	10	3	9	5	9	7	1	1		3		1			1		1		104
— 2 230 239				1	4	1	6	5	5	5	16	8	5	7	4	7	4	6	6	5	2	4	1		2		2	1					107
— 1 240 249				3	2	6	7	10	13	6	9	11	8	10	8	3	2	1	1	1	1				1	1							104
0 250 259	4		8	6	4	8	11	13	9	8	5	9	7	4	6	6	4	4	2	1			2		1								122
1 260 269		4	1	1	4	6	10	6	8	4	6	5	5	4	1	3	4		1		2												75
2 270 279	1	3	2	5	9	7	6	9	9	8	3	5	1	5	1	1		1	2														78
3 280 289		6	3	6	6	5	7	7	3	7	2		2	1																			55
4 290 299			3	3	5	4	5	6	1	1	1	1	1	1		1																	33
5 300 309	3	4	9	12	3	4	5	3	1	1	2			2																			46
6 310 319	1	4	5	4	4	1	1	1																									21
7 320 329	3			3	3	1					1																						11
8 330 339		2	1	2	1	1					1																						8
9 340 349			2	1																													3
10 350 359	2	1	2	3																													8
11 360 369																																	0
12 370 379	2																																2
13 380 389		1																															1
Weight deci-mg.	18	28	36	56	47	51	61	70	61	54	73	58	41	64	44	37	39	33	33	25	17	12	7	9	5	6	3	5	2	2	2	1	1000

FIG. 1. Correlation in oats.[3] Average weight of grains subject, number of grains per head relative. Coefficient of correlation, -0.595 ± 0.013.

X_1 \ X_2	−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	0	1	2	3	4	5	6	7	8	9	Head cm.
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
—10 150 159	1							1													2
— 9 160 169								1					1					1			3
— 8 170 179										1	1			2	2				1		7
— 7 180 189										1		3	4	3	4	1	2				18
— 6 190 199										2	3	5	11	1	3	2		1			28
— 5 200 209						2		2	2	3	11	14	13	10	8	3	4	1			73
— 4 210 219				1	1		1	1	4	8	10	15	18	18	11	3					
— 3 220 229								2	5	15	17	16	24	11	6	7		1			104
— 2 230 239							2	3	10	14	18	17	17	14	7	3	2				107
— 1 240 249					1	1	4	7	8	12	21	18	16	10	4	1				1	104
0 250 259	1		2	1	4	2	4	10	20	21	17	9	17	7	5	1	1				122
1 260 269					2		3	6	12	14	13	11	7	3	3	1					75
2 270 279			1	1	2	2	3	12	8	13	7	13	8	5	2	1					78
3 280 289					2		9	5	7	10	10	4	4		3	1					55
4 290 299						1	1	5	8	11	2	2	2		1						33
5 300 309					1	5	9	8	7	7	6	2			1						46
6 310 319				2		1	4	7	2	3		1				1					21
7 320 329				2	1		1	3	2	2											11
8 330 339						1	1	3	1		1			1							8
9 340 349						1	1	1													3
10 350 359				1	3		2	1	1												8
11 360 369																					0
12 370 379					2																2
13 380 389						1															1
Weight deci-mg.	2			8	19	17	45	78	97	137	137	130	142	91	54	25	9	4	1	1	1000

FIG. 2. Correlation in oats. Average weight of grains subject, length of head relative. Coefficient of correlation, -0.511 ± 0.015.

[3] The weights of the grains in the first five figures are expressed in deci-milligrams. The lengths are expressed in centimeters. In Fig. 6 the weight is expressed in milligrams and the volume in cubic millimeters.

resented an entire plant. The variety is well defined morphologically, but evidently contains various races or biotypes.

Among other data secured was the height of culm, the length of head, the number of grains per head and the average weight of kernel. The various measurements were correlated and the results prove very interesting.

Fig. 1 shows the correlation existing between the average weight of kernel as subject and the number of grains per head as relative. A strong negative correlation is noticed, amounting to very nearly 60 per cent. In other words, the greater the number of grains per head, or, in reality, the larger the head as regards grain, the less the average weight per kernel.

The mean of the number of grains per head, of the population studied, is 22.098 and the mean weight per kernel is 24.913 mg.

The regression coefficient of the number of grains relative to the average weight of grain is — 1.98. In other words, if we should select grains for planting that weigh, for instance, 30 mg. and above, they would on the whole be selected from heads containing only about 12 or 13 grains, which represent heads considerably below the mean. There would doubtless be an occasional grain from heads above the mean, but such grains would be uncommon and the increasingly larger heads would be more and more sparsely represented in the grain selected for planting.

Fig. 2 shows the correlation existing between the average weight of kernel as subject and the length of head as relative. As the number of grains is quite dependent upon the length of head we should expect to find a correlation existing between the two, somewhat similar, as is shown in Fig. 1. The actual correlation is negative and amounts to 51 per cent. The mean length of the head is 13.583 cm.

The regression coefficient of the length of the head relative to the average weight of grains is — 0.379. That is, if we should select grains for planting that weigh, for instance, 30 mg. and above, they would in general be

X_2	−36	−34	−32	−30	−28	−26	−24	−22	−20	−18	−16	−14	−12	−10	−8	−6	−4	−2	0	2	4	6	8	10	12	14	16	18	20	Height cm.
	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81	83	
	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	
X_1																														
−10 150 159	1										1																			2
−9 160 169															1	1									1					3
−8 170 179														1		1		1	1	1				1	1					7
−7 180 189																		3	2	5	6		2							18
−6 190 199														2	1	2	1		3	1	6	8	1	3						28
−5 200 209						1					2	2		1		4	5	2	11	11	5	10	7	7	1	2	2			73
−4 210 219						1				1		2	1	3	4	5	5	5	13	11	9	16	6	4	3		2			91
−3 220 229												1	3		2	13	9	8	9	13	10	8	8	10	4	3	3			104
−2 230 239										1	1	1	2	3	4	7	9	11	10	14	9	9	13	3	4	4	1	1		107
−1 240 249										1	2	4	1	1	7	7	15	13	8	12	16	8	3	1	2	1	2			104
0 250 259	2					1		1	2	4	1	5	9	10	4	6	10	10	9	7	9	16	9	4	3					122
1 260 269									1		3	3	1	5	7	13	6	5	3	1	8	8	5	2	3	1				75
2 270 279				1	1	1	1			2	1	5	5	5	5	6	4	12	4	6	10	2	3	2		1			1	78
3 280 289						2		1	1	1	2	4	2	5	12	3	2	5	5	5	1	1	1	1				1		55
4 290 299								2		1			4	3	3	2	5	3	2		2	2				3	1			33
5 300 309						1	1	2	1	3	3	6	5	4	5	4	1	2	3	1	1	2		1						46
6 310 319								1	2		3	2	4	3	3	1			1		1									21
7 320 329					1			1		1		2	1	1	1		2	1												11
8 330 339											1	3			2			1				1								8
9 340 349									1		1					1														3
10 350 359						1	1				1	1	3					1												8
11 360 369																														0
12 370 379												1	1																	2
13 380 389												1																		1
Weight deci-mg.	3	0	0	1	2	8	3	8	8	15	22	43	42	47	61	76	74	83	84	88	93	91	58	39	22	15	11	2	1	1000

FIG. 3. Correlation in oats. Average weight of grains subject, length of culm relative. Coefficient of correlation, — 0.404 ± 0.017.

X_2	−14	−12	−10	−8	−6	−4	−2	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	No. of grns.
	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	
	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	
X_1																														
−11 80 89															1															1
−10 90 99								3																						3
−9 100 109						1						1													1					3
−8 110 119						1		1						1																3
−7 120 129		1	1			1					1	1			1															6
−6 130 139				1	1		1	1		2	3	2	1				1													13
−5 140 149						2	1		3	1	1		1																1	10
−4 150 159				1	1	1	2	1	3	2	2	1	1	2																17
−3 160 169				2	1	1	5	3	9	1	2	1						1		1		1								28
−2 170 179		1			5	3	11	3	1	4	3	4	2	2	2															41
−1 180 189			1	1		4	4	5	9	5	5	3	6	2	3			1												49
0 190 199				1	4	2	5	9	6	4	9	3	4	2	1	1				1										52
1 200 209		1	1	2	3	1	2	8	5	7	4	3		1	1		1													40
2 210 219					1	1	6	3	4	3		2	4																	24
3 220 229		1		1		1	4	3	1	3	4		5	1			1													25
4 230 239					1	2	3	3	3	2	1		1																	16
5 240 249					1			1		1	1	1					1													6
6 250 259		2				1	2	1				1																		7
7 260 269						1							1																	2
8 270 279												1	1																	2
9 280 289	1	1																												2
10 290 299		1																												1
11 300 309							1																							1
12 310 319							1																							1
13 320 329																														0
14 330 339																														0
15 340 349																														0
16 350 359																														0
17 360 369																														0
18 370 379																														0
19 380 389																														0
20 390 399														1																1
Weight deci-mg.	1	8	3	9	18	23	48	45	44	35	36	24	27	12	9	1	4	2	0	2	0	1	0	0	1	0	0	0	1	354

FIG. 4. Correlation in winter wheat. Average weight of grains subject, average number of grains per head relative. Coefficient of correlation, — 0.115 ± 0.031.

selected from heads in the neighborhood of 11.5 cm. long. We should have to select the shorter heads in order to secure the larger grains.

Fig. 3 shows the correlation existing between the average weight of kernel as subject, and the total height of culm, including the head, as relative. The correlation is still negative and amounts to 40 per cent. The mean length of the culm is 61.74 cm.

The regression coefficient of the length of the culm relative to the average weight of grain is — 0.987. As in the last example, the selection of grains weighing 30 mg. and above would imply that they had come from culms about 56 cm. long, or about 5 cm. below the mean.

As a summary, plants with shorter culms, shorter heads, and with a smaller number of grains, bear on the whole grains of a greater weight. The opposite of course is equally true.

If the data had been taken of a pure strain of oats, of the variety studied—of a number of plants that had come within a few generations from a single mother plant—then the correlations might have varied slightly from those given. If data were accessible of another variety, then we might suspect even greater deviation from the figures given. Variation in the same variety from year to year may be expected. However, there is nothing to lead us to believe, from an *a priori* standpoint, that the data given would be essentially changed.

If data were taken on oat plants grown in hills, then we might get less decided negative correlations than those given where the plants were grown under field conditions. The variability of the number of grains, the height of plant and the length of head might be less, while the variability of the average weight of grain might not be much different.

The following table shows the coefficients of variability expressed in per cent. of the various factors that have been discussed.

The factor of the number of grains is evidently the much more variable one and perhaps under hill condi-

X_2 / X_1	−34 37 38	−32 39 40	−30 41 42	−28 43 44	−26 45 46	−24 47 48	−22 49 50	−20 51 52	−18 53 54	−16 55 56	−14 57 58	−12 59 60	−10 61 62	−8 63 64	−6 65 66	−4 67 68	−2 69 70	0 71 72	2 73 74	4 75 76	6 77 78	8 79 80	10 81 82	12 83 84	14 85 86	16 87 88	18 89 90	20 91 92	22 93 94	24 95 96	26 97 98	Height cm.
−11 80 89																						1										1
−10 90 99																				1		1			1							3
−9 100 109							1									2																3
−8 110 119										1								1	1													3
−7 120 129					1	1					1			1			1		1													6
−6 130 139	1				1				1					1	2	2	4			1												13
−5 140 149							2			1		1			1	4										1						10
−4 150 159					1					1	1	2		1	1			2		4		1	1			1	1					17
−3 160 169							1	1	1	1	2	1			3	1	1	2	1	1	4	3	1		1		2	1				28
−2 170 179				1				1	1	4	2			3		3	5	1	5	4	3	3	2	1		1				1		41
−1 180 189						1	2		1	1	1	3			3	2	3		4	6	3	5	5	1	3	1	1	3				49
0 190 199		1				1			1	3	1	3	4		6	3	2		2	1	6	2	5	3	3	1	1	1		1	1	52
1 200 209							1	2	2			3	3		2	1	1	2	4	5	4	1	1	2	1	1	2	1		1		40
2 210 219			1								1					1	2	3	2	2	1		2	1	2	1	4			1		24
3 220 229					1							1	2	2		2	2		3	2	3	2		1	1	1	1	1				25
4 230 239												1			3			1		1	1	1		1	2	2	1	1		1		16
5 240 249										1		1			1						1	1					1					6
6 250 259								2							1								1		1	1				1		7
7 260 269																			1											1		2
8 270 279																	1					1										2
9 280 289					1	1																										2
10 290 299							1																									1
11 300 309																									1							1
12 310 319																									1							1
13 320 329																																0
14 330 339																																0
15 340 349																																0
16 350 359																																0
17 360 369																																0
18 370 379																																0
19 380 389																																0
20 390 399																1																1
Weight deci-mg.	1	1	1	1	5	4	8	6	7	13	9	16	9	8	23	22	22	12	24	28	26	22	18	10	17	11	14	8	0	7	1	354

FIG. 5. Correlation in winter wheat. Average weight of grains subject, average length of culm relative. Coefficient of correlation, 0.16 ± 0.034.

X_2 / X_1	−6 14	−5 15	−4 16	−3 17	−2 18	−1 19	0 20	1 21	2 22	3 23	4 24	5 25	6 26	7 27	8 28	Vol. cu. mm.
−8 19		1														1
−7 20	1	3	2													6
−6 21		1	2							1						4
−5 22			4	2												6
−4 23			2	6	1					1						10
−3 24				4	8											12
−2 25				2	12	10										24
−1 26					4	13	3									20
0 27						7	16									23
1 28						1	12	5	1						1	20
2 29							1	13	4							18
3 30							1	7	8	1						17
4 31									6	2						8
5 32									1	4	4					9
6 33										2	3					5
7 34											1	1				2
8 35												1	1			2
Weight mg.	1	5	10	14	25	31	33	25	20	11	8	2	1	0	1	187

FIG. 6. Correlation in winter wheat. Average weight of grains subject, average volume of grains relative. Coefficient of correlation, 0.896 ± 0.009.

tions it would be somewhat reduced, though this is only problematical.

Factor.	Coefficient of Variability.
Number of grains	54.5 ± 2.33
Average weight of grains	14.5 ± 0.48
Length of head	19.7 ± 0.68
Length of culm	14.2 ± 0.47

Since the above was written it has been found that the small oat heads bear a somewhat larger percentage of single grains than the large heads. If this factor be considered, the negative correlations would be somewhat decreased but probably not materially.

Correlation Data of Wheat

In looking over the literature some unreduced winter wheat data were found in Bulletin 78 of the Bureau of Plant Industry by Dr. T. L. Lyon. A portion of this data was thrown on to correlation tables and is given herewith.

Fig. 4 shows the correlation existing between the average weight of kernel as subject and the average number of grains per head as relative. Both the weight and number are averages for the entire plant. The figures are thus not quite comparable to those given for the oat plants, but are doubtless nearly so. Data for only 354 individual plants are given, but this number of plants represents a considerably larger number of culms. The correlation is negative and is a little over 11 per cent. The regression of the average number of grains relative to the average weight of grains is much diminished and a selection of seed of either very high or of very low weight would not indicate that the seed was from plants located any appreciable distance from the mean, as far as average number of grains is concerned.

Fig. 5 shows the correlation existing in winter wheat between the average weight of kernel as subject and the average height of culm as relative. As in the previous case, data for only 354 individuals are given. Instead of a negative correlation, as in all previous cases, we have

here a positive correlation, amounting to 16 per cent. This is a weak correlation. The regression of the average height of culms is very slight. Selection of any particular weight of seed would not imply that any particular heights of plants were involved.

It is interesting to note that the correlations given of winter wheat hold about the same relations to each other as do the corresponding correlations of the oats.

Relation of Size to Volume of Grain

But little accurate data on this point are available. We should expect to find a close correlation. The data given in Fig. 6 are taken from Bulletin No. 78 mentioned previously. It is seen that there is an almost perfect correlation existing between the average weight of kernel and the average volume per kernel. The three outstanding individuals suggest errors rather than extreme variations.

Summary

If oat populations in general show constants similar to those given, then the experimenter selecting the large grains is not selecting from what is commonly considered the best plants, and *vice versa*. If the plants from large grains produce a better yield, then they must do so by virtue of the increased vigor of the embryo and the increased amount of food supply. If we consider that the size and yield of the mother plant have an influence upon the size and yield of the daughter plants, then we must consider that this influence is decidedly less than the influence exerted by the size of the seed. If the size and yield of the mother plant have no effect upon the offspring, then we might expect the yields from different weights of seed to be somewhat in proportion to the weights of seed.

Despite all that has been written on the foregoing points we have very little accurate knowledge pertaining thereto, especially relative to the influence of selection upon the close pollinated cereals.